PREPLANTING SITE TREATMENTS AND NATURAL INVASION OF TREE SPECIES ONTO FORMER AGRICULTURAL FIELDS AT THE TENSAS RIVER NATIONAL WILDLIFE REFUGE, LOUISIANA

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Abstract—As part of a study of oak planting techniques for bottomland hardwood afforestation we examined the natural invasion of woody species onto former agricultural fields at Tensas River National Wildlife Refuge. Three replications of 14 treatments were established as 0.4 hectare (1 acre) plots in a complete randomized block design. Combinations of these treatments were used to examine the effects of disking and distance from existing forest edges on natural invasions of woody species. Each one-acre plot was sampled with 4 subplots, 100 m^2 each, for all seedlings greater than 0.3 meters in height. A total of 18 woody species, dominated by elm(*Ulmus* sp.) (41 percent), ash(*Fraxinus pennsylvatica*) (25 percent), and sugarberry(*Celtis laevigata*) (21 percent), and with lower frequencies of honey locust(*Gleditsia tricanthos*), deciduous holly(*Ilex decidua*), persimmon(*Diospyros virginiana*), hawthorn(*Crataegus* sp.), sweetgum(*Liquidambar styriciflua*), and black willow(*Salix nigra*), were noted. The treatment with little or no disturbance, no till, had more individuals (814.6/ha or 325.8/ac) than the strip disked(SD)(643.7/ha or 257.5/ac) or disked(DD)(380.2/ha or 152.1/ac) treatments. These differences in invasion rates may have been related to several aspects of disking. Disking may eliminate existing agricultural rows and furrows reducing microtopographic variation, bury seeds too deeply, or expose seeds to drying. Distance from the forest edge also affected invasion rates with an average of 1038.8 individuals per ha (415.5/ac) between 129 - 259m, 635.1/ha (254.0/ac) between 260 - 406 m, and 301.3/ha (120.5/ac) at greater than 406 m. The nearest mature forest edge was 129 m distant. Woody invaders were found up to 640 m from the nearest forest edge. Although factors such as soil type, herbivory, and moisture influence the woody plant species found in these fields, initial disturbance and distance from the forest edge was shown to be important factors determining natural invasion success.

INTRODUCTION

Reestablishment of bottomland hardwood (BLH) forests throughout the Lower Mississippi River Valley (LMRV) has increased in the last 10 years. Interest in replanting BLH forests to agricultural fields arises from increased land availability associated with decreased farm products income and the understanding that only a small amount (2.8 million ha) of historical (10 million ha) bottomland hardwoods remain in the LMRV (National Research Council 1982; Hefner & Brown 1985). Over the past 10 years 77,698 hectares were planted to BLH species in Arkansas, Louisiana and Mississippi by the U.S. Fish & Wildlife Service, the U.S. Army Corps of Engineers, the Natural Resources Conservation Service, the Arkansas Game and Fish Commission, the Louisiana Department of Wildlife and Fisheries and the Mississippi Department of Wildlife Fisheries and Parks. More land (89,009 ha) is expected to be planted over the next five years by these same agencies (King and Keeland 1999).

Initially the main focus of these plantings was the establishment of hard mast species such as oaks and pecan with the expectation that light seeded species would invade naturally. Most stands were reforested to provide habitat for game species, but recently, land managers have realized that maintaining a diverse plant community is important to mammals and birds that live all or part of their lives in bottomland hardwoods (Daniel and Fleet, 1999). This realization has shifted the focus of reforestation efforts to include the planting of many additional tree species such as ash, sugarberry, sweetgum and baldcypress (King and Keeland 1999). But, the role that natural invasion will provide for increased diversity and structural complexity remains to be understood. Questions as to the extent that natural invasion can be counted on to provide additional species and increase the tree diversity and structural complexity of the developing stands remain unanswered.

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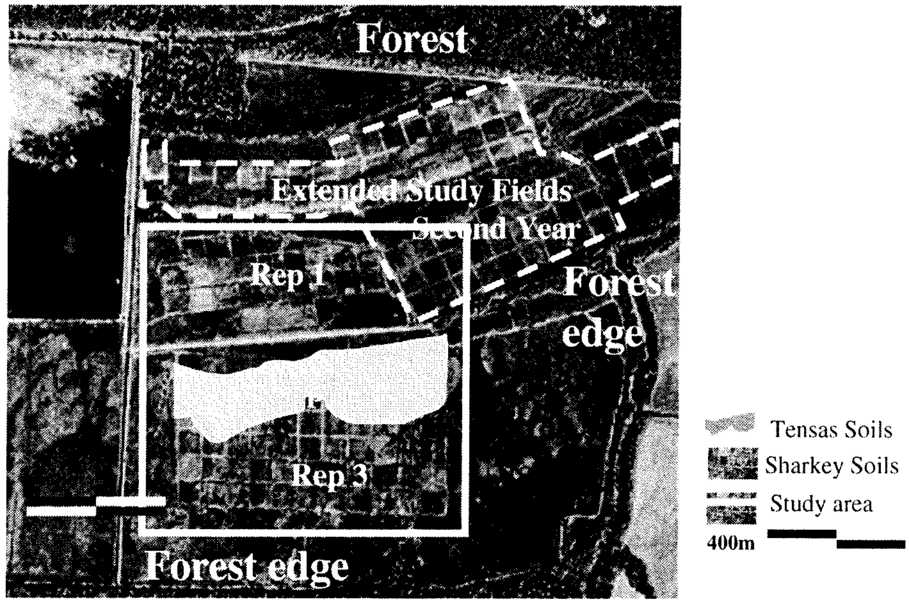

Figure 1—Photograph of the Tensas River NWR study area (1995) showing the one-acre plots outlined by 10 m wide buffer strips. Forest edges for possible sources of seedlings are noted. Extended study fields are are part of a subsequent year study that are yet to be counted. North is to the top of the photograph.

In 1993 a reforestation study was jointly developed between the U.S. Fish & Wildlife Service, the Louisiana Department of Wildlife & Fisheries and the School of Forestry, Wildlife and Fisheries at Louisiana State University. The purpose of the study was to examine the establishment, survival and growth responses of selected oak species to several planting techniques. Over time additional woody species invaded the study plots and provided another aspect to the study. The purpose of this portion of the overall study is to examine the natural invasion of woody species onto these reforested areas to determine if the planting techniques (for the oaks) affected invasion rates.

METHODS

The study was conducted on the Tensas River National Wildlife Refuge (Tensas NWR) in northeastern Louisiana. The only topographic relief on the site consists of an old levee of the Tensas River. The levee runs east/west through the study area and is about 1 to 3 meters higher than the surrounding floodplain. Tensas soils, very deep, somewhat poorly drained, very slowly permeable, are found on the levee while Sharkey clay soils, very deep, poorly and very poorly drained, very slowly permeable, are found on the surrounding floodplain. The study area, which was fallow for less than one year before planting, was divided into one acre study plots (figure 1). Treatments were assigned as a randomized complete block design involving six direct seeding treatments as follows: (1) double disk, maximerge direct seed (DD); (2) double disk, maximerge direct seed, roll (DR); (3) strip disk, maximerge direct seed (SD); (4) no till, maximerge direct seed (NT); (5) single disk, cyclone direct seed, single disk (CS); (6) single disk, cyclone direct seed, single disk, roll (CR). The plots were direct seeded during the fall (October 1993) and spring (March 1994). Two oak species were planted, Nuttall (*Quercus texana*) and water oaks (*Q. nigra*), with one species per plot.

Two additional treatments (hand and machine planting of bare-root seedlings) were initiated December 1993. Each of the 14 treatments was replicated three times for each species producing a total of 84 treatment plots.

Fields were not bushhogged, but disking for selected treatments was accomplished in September 1993. Fall treatments were planted in October and spring treatments were planted in March 1994. All post-planting disking associated with cyclone direct seeding was accomplished immediately after planting. Seed and seedlings were kept chilled before planting (personal communication John Simpson, USFWS Tensas River NWR).

Each of the 84 one-acre study plots was sampled during November 1999 using 4 circular subplots, 100 m^2 each, established 20 m in toward the center from the corners of each field. All woody species greater than 0.3m in height was tallied from each subplot. Saplings were categorized by height into the following classes: (1) > 0.3 to < 0.5 m, (2) > 0.5 to < 1.0 m, (3) > 1.0 to < 1.4 m, (4) > 1.4 meters to < 2.5 cm diameter at breast height (DBH, at 1.4 m) and (5) all trees > 2.54 cm DBH. Diameters were recorded only for those trees greater than 2.5 cm DBH.

Data on other woody perennial species such as *Sabal minor* (palmetto) was noted during the sampling. The dominant herbaceous species were noted for each plot, but a complete census of the herbaceous vegetation was not attempted. Data were analyzed by ANOVA using JMP (SAS 1988).

RESULTS AND DISCUSSION

Species Summary

A total of 4,496 individuals of 18 woody plant species, including the oaks, was observed on the plots (table 1). Average stem density across all plots was 541.9/ha (219.4 /ac) for invaders and 781.6/ha (316.4 /ac) for planted oaks. The presence of Nuttall oak, water oak on some plots where these species were not planted, and the presence of some willow oak (*Q. phellos*) on more than half the subplots suggests a possibility of acorn or seedling contamination at the time of planting. Willow oak was not one of the oak components.

Exclusive of the oaks, 1,821 stems were counted in all subplots, with three species groups dominating; elms (*Ulmus alata, U. Americana, and U. crassifolia*, 231.8/ha), ashes (*Fraxinus pennsylvatica,* 132.4/ha), and sugarberry (*Celtis laevigata,* 109.5/ha). These three species accounted for 85.1 percent of all naturally invading saplings encountered in the study. Frequency on subplots were 90.5, 61.9, and 86.9 percents for elm, ash, and sugarberry, respectively. These data show that not only were elms, ash, and sugarberry the most numerous species, but that they occurred on the greatest proportion of the plots. Elms and sugarberry were the most ubiquitous. Honey locust (*Gleditsia tricanthos*) and deciduous holly (*Ilex decidua*) was also common, occurring on 30 and 36 percent of the plots, respectively. Although most species were fairly evenly distributed among and within plots, two species, hawthorns (*Crataegus* sp.), and persimmons (*Diospyros virginiana*), exhibited clumped distributions. Sugarberry occurred in 47 percent of the plots and in 25 percent of the subplots as the only woody invader species. In general, those plots with sugarberry as the only woody invader were the furthest plots from the nearest forest edge. Elms occur in 72 percent of all subplots but never occurred without other tree species within a subplot. These occurrences are linked to distance but are also to related to soil type and herbaceous communities. Many of the dominant herbaceous plants act as perches for small songbirds and as such may help promote increased woody species density and diversity. These same herbaceous plants may also act as cover for rodents that feed on the seeds and seedlings.

Species Diversity

A total of 18 woody plant species invaded onto the study plots. The number of species may have been greater, but, due to the number of volunteers helping on the project, no attempt was made to identity hawthorns, or wild cherry to species. In addition, 31 elm saplings were listed as elm sp. on the data sheets. Forty two percent of the species, including boxelder, red maple, swamp dogwood, sweetgum, swamp cottonwood, saltbush, water hickory, and wild cherry make up only 3.6 percent of the saplings counted. The most abundant species, sugarberry, ash, and elms, make up 82.1 percent of the total number of individuals counted but are only 22.2 percent of the individual species represented within this study.

On average, 541.9 saplings/ha (219.4 /ac) were counted on the subplots. Twelve percent of all subplots at greater than 335 m from a forest edge did not have any invaders, but none of the one-acre plots were lacking natural invaders. In a previous study, where all tree seedlings were recorded, several 100 m^2 plots were empty (Allen and others, 1998). The proximity of these fields to a forest edge was a stronger influence on natural invasion rates than treatment effects ($p < .0001$). Several seedlings less than 30 cm were observed on many plots but were not counted as part of this study. It is probably that many more seedlings less than 30 cm tall were present but not counted.

All species encountered in this study, excluding the Prunus spp., are facultative to obligate wetland plants. Survival and growth of some species may have been affected by much less than average rainfall during the growing seasons of 1998 and 1999.

Herbaceous Vegetation

The herbaceous layer generally consisted of a mixture of herbs, grasses and vines similar to that reported by Allen and others, (1998). Most plots were dominated by one species or a combination of two to four species. Dominant herbaceous vegetation included *Solidago* sp. (24.0 percent relative frequency), *Lythrum salicare* (21.3 percent), *Campsis radicans* (12.7 percent), *Sorgham halapense* (8.0 percent), and *Andropogon glomeratus* (7.14 percent). Several other relatively uncommon species noted on the plots included *Eupatorium* spp., *Verbena brasilensis*, and Aster spp. *Lythrum salicare* was the only observed species considered to be a noxious weed (Kartez, 1999).

Although some plants common to very wet areas, such as *Iva annua* and *Juncus effusis*, were found on the plots, their abundance may have been much less than is normal for this area. The drought of 1998 and 1999 (figure 2) caused many wet areas to dry out completely and probably had an impact on the herbaceous vegetation. It is possible that wet-site species may have been more abundant if the study has been conducted during a wetter time.

Although many areas were dominated by dense mats of vines such as *Rubus* sp., *Campsis radicans* and *Smilax* sp., these mats were generally small when compared with the plots size and were dispersed throughout the field. Other vines such as peppervine (*Ampleopsis arborea*) and grape (*Vitis* sp.) occurred sparingly within the fields.

Treatment Effects on Natural Invasion

Soil disturbance in the form of disking has been shown to have a significant effect on natural invasion rates (Allen and others 1998). In that study disking was shown to have a negative effect on the numbers of woody plants invading the plots. The effect of disking, however, appears to decrease through time(McCoy 1998). In the current study there were greater numbers of some species, especially the elms, on plots that had received little or no disking (SD or NT), but the effect was not significant when this study was sampled, at the end of the 6th growing season. None of the other silvicultural treatments examined in this study affected the rates of natural invasion by woody species. However, specific treatments that were positive for success of oaks were generally negative for the success of natural invaders.

Table 1—Mean number of stems/ha by size class and species. Size classes are: Class 1- > 30 to < 50, Class 2- > 50 to < 100, Class 3- > 100 to < 140, Class 4- > 140 to < 2.5 cm diameter at 140 cm height (DBH), Class 5- > 2.5 cm DBH. Frequency and stem densities are given for all size classes combined.

	CLASS					Frequency		Stems	
Species	1	2	3	4	5	Abs.	Rel.	Total	per / ha
Box Elder	0.0	0.3	0.0	0.3	0.0	2.0	2.4	2.0	0.6
Red Maple	0.3	2.7	0.9	0.0	0.0	10.0	11.9	13.0	3.9
Baccharis	0.0	0.0	0.0	3.6	0.0	6.0	7.1	12.0	3.6
Water Hickory	0.0	0.0	2.4	0.3	0.9	6.0	7.1	12.0	3.6
Sugarberry	3.6	51.2	33.9	20.5	0.3	73.0	86.9	368.0	109.5
Swamp Dogwood	0.0	0.3	0.0	0.0	0.0	1.0	1.2	1.0	0.3
Hawthorn	1.5	3.9	0.6	0.6	0.0	14.0	16.7	22.0	6.5
Persimmon	0.0	1.8	1.8	5.1	0.3	10.0	11.9	30.0	8.9
Ash	0.0	8.6	30.7	89.3	3.9	52.0	61.9	445.0	132.4
Honey-locust	0.0	1.5	2.1	7.7	2.4	25.0	29.8	46.0	13.7
Deciduous holly	2.4	3.3	2.7	3.9	0.0	30.0	35.7	41.0	12.2
Sweetgum	2.4	2.4	0.9	0.3	0.0	19.0	22.6	20.0	5.9
Swamp cottonwood	0.0	0.0	0.0	5.3	0.6	6.0	7.1	6.0	1.8
Wild cherry	0.0	0.0	0.0	0.0	0.3	1.0	1.2	1.0	0.3
Black willow	0.0	0.0	0.0	8.9	2.1	7.0	8.3	22.0	6.5
Elms	64.0	126.0	27.8	4.8	0.9	76.0	90.5	779.0	231.8
Total invaders	74.2	202.0	103.8	149.0	11.6	84.0	100.0	1821.0	541.9
Oaks	99.0	310.0	186.0	182.0	3.0	84.0	100.0	2626.0	781.5

Soils and elevation can also effect the establishment of tree species in old fields. In this study, greater numbers of sugarberry was found on the Tensas soil type along the natural levee of the Tensas River($p = 0.0458$).

Distance From Forest Edge / Seed Source

Distance from the nearby forest edge has been shown to have a significant effect on invasion rates (Allen and others 1998). A comprehensive analysis of the effects of distance on invasion rates is not possible in this study as no plots were closer than 129 m from the nearest forest edge and the subplot furthest from the forest edge was at a distance of 640 meters. We did, however, observe that the number of all invading species declined with increasing distance from the forest. Distances by quartiles (25, 50, and 25 percent of the individuals) showed 1038.8 individuals per ha (415.2/ac) between 129 - 259m, 635.1/ha (254.0/ac) between 260 - 406 m, and 301.3/ha (120.5/ac) at greater than 406 m. The numbers of subplots at each of the three distance regimes above were 45, 148, and 143.

General patterns of dispersal with distance, however, indicate differences for light versus heavy seeded species. Most (55.2 percent) light seeded species such as elms, ash, sweetgum, red maple, box elder, swamp cottonwood, and black willow occurred within 259 meters of the edge. Heavy seeded species seemed to follow one of two patterns. Species with the largest seeds, those usually transported by mammals, were typically found near the forest edge. This included species such as honeylocust and persimmon. Several species such as sugarberry, deciduous holly and hawthorns, usually transported by birds, were often found at greater average distances from the forest edge. Dispersal distances to be expected for any seed depends as much on the potential animals feeding on the seeds as on the seeds themselves (Johnson and others, 1985). However, soil type and therefore herbaceous communities associated with these soils differ with distance from the existing forest edge and could affect animal and bird use and seedling establishment rates.

Height classes and dbh

Overall, 51 percent of the saplings were less than 100 centimeters in height (table 1). The size class with the greatest number of saplings was 50-100 cm with 37.3 percent of all natural invaders. At the end of six growing seasons half the saplings were still at or below the average height of existing herbaceous vegetation and difficult to see at a casual glance. This makes the evaluation of afforestation success hard to measure and susceptible to seedling count errors. Even with a thorough search of the study subplots it is possible that some existing saplings were not observed or counted.

The short height of so many stems may be partially related to local browsing by deer and other herbivores. Many

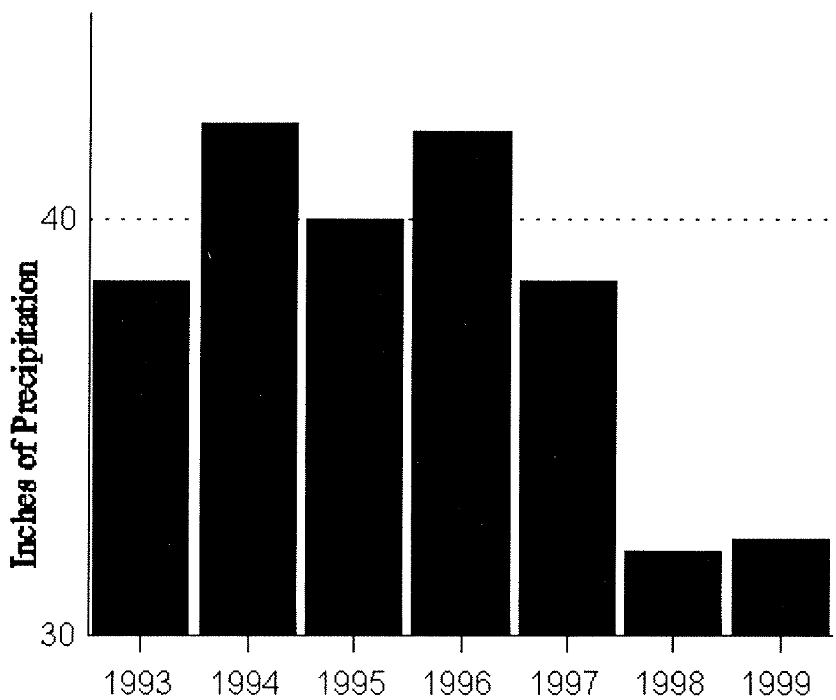

Figure 2—Inches of precipitation for the region of Tensas River NWR.

saplings, especially the elms and sugarberry, had obviously been damaged by browsing. The lower than average levels of precipitation for the years 1998 and 1999 may also have affected the growth of many saplings (figure 2).

Only 541 saplings (29.7 percent) were in excess of 140 cm tall, and only 2.1 percent of the trees had a measurable diameter (greater than 2.5 centimeters DBH). The average DBH of these taller saplings was 3.9 cm. Black willow had the largest mean DBH, 4.8 cm followed by honeylocust at 4.3 cm. The only other species with substantial numbers of stems greater than 2.5 cm DBH was ash, with an average of 3.3 cm. These three, fast-growing species represent 72.4 percent of all stems greater than 2.5 cm DBH. The honeylocust sapling's size may have been aided by reduced browsing associated with the large thorns all along the stem and branches. Honeylocust is intolerant of shade (Burns 1990) which may help explain the lack of shorter individuals of this species.

The distribution of saplings among the five height classes was highly variable among species (table 1). Sugarberry stems were distributed among all size classes, but perhaps under represented in the smallest size class. This may have been due to browsing. The distribution of ash stems was skewed toward the taller size classes. The low numbers of ash stems in the shorter size classes may not be related to browsing as very few ash stems showed any signs of herbivory. Of the 20 sweetgums counted in the plots these were mostly limited to the smaller size classes, but, again this did not seem related to browsing. Elms dominated the smaller size classes with few large stems. Browsing was evident on most elm stems and was probably a large factor in the observed greater numbers of stems less than 1m in height for this species.

CONCLUSIONS

Silvicultural planting treatments had little effect on the natural invasion of woody species onto these fields. Although some species, especially the elms, may be more numerous on plots with least disturbance (no till or strip disking) the effects were not significant at the 0.05 confidence level. The main factor affecting natural invasion rates was distance from the nearest forest edge. The effect of distance varied with species, seed size and disseminating agent (wind, birds, or other animals). Although the majority (75 percent) of most species with wind dispersed seeds were found within 392 m of the forest edge, some species with bird dispersed seeds were found in the most distant subplots, 640 m from the forest edge.

The effects of browsing on natural invasion and survival rates are not well understood. While many species, such as honeylocust, sweetgum, black willow and persimmon, appear not to have any browsing damage, other species, such as sugarberry, elms and the planted oaks, were heavily browsed. Browsing is probably having an effect on the successful establishment of many seedlings, but it appears that the species most heavily browsed are the ones invading in the greatest numbers. This level of browsing may not have an overall detrimental effect on the developing woody plant community as it may be promoting a more even species composition.

Height of the herbaceous plant community must be explicitly considered when assessing the success of a reforestation effort. In this study and in Allen and others (1998) the herbaceous vegetation was about 1 - 1.2 meters in height. At least half the saplings were below this height making them difficult to observe without a concerted effort. Persons conducting an evaluation before five to six years post planting may have difficulty finding all saplings within the sample area.

Interactions of the different effects such as distance and direction from existing forest edges, soil types, and disturbance makes analysis of this data complex. Unknown effects that further complicate the analysis includes browsing, existing forest edge species composition, and local climatic effects. However, an understanding of natural invasions onto former agricultural fields is being refined as more studies are completed.

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